63-2-4

Operations Analysis Working Paper Nr. 7

THE IMPACT OF FACTORS ON GROSS REQUIREMENTS

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$1.60

October 1960

Operations Analysis Office
Directorate of Plans and Programs
Headquarters, Air Materiel Command

UNCLASSIFIED

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I. Introduction

On 8 January 1960, the Director of Supply in Headquarters Air Materiel Command (Major General Frank A. Bogart) requested the establishment of a full time MCS study group "to review the present Hi-Valu consumption item requirements methods and make recommendations to me with regard to simplification possibilities." On the same date, General Bogart requested the participation of Hq AMC Operations Analysis personnel in the work of this study group, on a consultant basis; the Director of Plans and Programs (Brigadier General Donald L. Hardy) approved the OA participation, and the author of this paper was assigned to this project.

On 20 January 1960, at a meeting of the study group, Mr. Walter H. Nelson, Jr., asked me to study the effects of variances in certain elements or "factors" of the requirements computation. This study was accomplished and was presented to the members of the study group, and was subsequently included in the 5 March 1960 briefings to General Bogart, along with the full findings of the study group. Following this, a memorandum from the AF Spares Study Group requested that my study of factors be published in an operations analysis paper. It was understood that such a paper would be useful in connection with the education and orientation of personnel in the field of logistics.

II. The Study

The problem can be stated as follows: Measure the effect on Gross Requirements when factors vary from certain specified values or "standards." To keep the problem small enough to permit early solution, the following assumptions were to be made:

a. The logistic concept and system are to be as presently prescribed in regulations and manuals;

b. The gross requirements formula is given;

c. A specific value will be set as the "standard" for each factor.

The standard factors were set as shown in Figure I below. They are merely a set of typical factors which an Item Manager might be using in his requirements computation, and were prescribed in order to permit sample or illustrative computations to be made.

FIGURE I

Program (P) = 10,000 flying hours per month [1]

Lead Time (LT) = 9 months

Repair Cycle (RC) = 3 months

Depot Repair Percent (DRP) = 100%

Stock Level (SL) = 1½ months, 15 days at depot and 30 days at bases

Issue Rate (IR) = .20 per 100 flying hours (or .0020 per FH)

Wearout Rate (WO) = .02 per 100 flying hours (or .0002 per FH)

The "Variances" of interest were prescribed as shown in Figure II below. These variances were to be processed, singly and in combination, to study the effects that various changes or errors in the factors would have on gross requirements.

[1] Throughout this paper "program" is used to mean monthly program.

FIGURE II

P	- 12½%, - 25%, - 37½%
LT	± 33 1/3%
RC	± 33 1/3%
DRP	None
SL	None
IR	± 20%, ± 40%
WO	± 20%, ± 40%

The formula to be used was furnished in verbal form, as seen immediately below. To permit manipulation of the factors, the author translated it into the symbolic forms shown in equations 1 and 2.

Gross Requirements =

Program x 12 x wearout rate

plus

Program x lead time x wearout rate

minus

Program x repair cycle x wearout rate

plus

Program x depot repair percent x repair cycle x issue rate

plus

Program x stock level x issue rate

$$GR = (P)(12)(WO) + (P)(LT)(WO) - (P)(RC)(WO) + (P)(DRP)(RC)(IR) + (P)(SL)(IR) \qquad \text{(Equation 1)}$$

$$GR = P\left[WO(12 + LT - RC) + IR(DRP \times RC + SL)\right] \qquad \text{(Equation 2)}$$

When the standard factors are inserted in Equation 2 the results are as shown in Figure III.

FIGURE III

$$GR = P\left[WO(12 + LT - RC) + IR(DRP \times RC + SL)\right]$$

$$= 10{,}000\left[.0002\ (12 + 9 - 3) + .0020\ (3 + 1.5)\right]$$

$$= (24 + 18 - 6) + (60 + 30)$$

$$= 36 + 90 = 126$$

$$(29\%) + (71\%) = (100\%)$$

As a means of crystallizing the effects of factor changes, the following definition was then introduced:

Factor Impact = The extent to which a change in a factor is transmitted to Gross Requirements.

$$I = \frac{\%\ \text{change in GR}}{\%\ \text{change in the Factor}} \qquad \text{(Equation 3)}$$

This concept of Factor Impact is essentially equivalent to a sensitivity analysis, in which we are inquiring about the extent to which the gross requirement for an item is sensitive to changes in the values of the factors used in computing that requirement. Once portrayed this way, the analysis leads directly to the following conclusion: the degree of Impact of a factor is equal to the original fraction of the Gross Requirement to which that factor contributed. Thus if some factor (e.g., the Issue Rate) had contributed to 71% of the original requirement, its Impact during a factor change would be 71%; if this factor changed by + 30%, the Gross Requirement would change by (+ 30%) times (+ 71%), or by + 21.3%.

The above conclusion is sufficiently general that it obviated the need to make the numerous sample calculations envisaged in the original statement of the problem, and in particular made it unnecessary to run computations using the variances cited in Figure II above.

For the standard factors cited in Figure I above, the appropriate Impact values are directly discernible from Figure III. These are recorded below in Figure IV.

FIGURE IV

Factor	Impact
Program	100%
Wearout Group [WO(12 + LT - RC)]	29%
WO alone	29%
LT alone	14%
Issue Rate Group [IR(DRP x RC + SL)]	71%
IR alone	71%
DRP alone	48%
SL alone	24%
Common Factor	
RC	43%

The following examples may help to interpret the meaning of Figure IV:

a. If P goes up 37%, GR goes up 37%;

b. If P goes down 24%, GR goes down 24%;

c. If WO goes up 90%, GR goes up 26% (90% times 29%);

d. If LT goes down 30%, GR goes down 4% (30% times 14%).

It is worthy of note that all the factors except P affect the Impact of one another, as follows:

a. Those which are combined through multiplication reinforce one another's Impact;

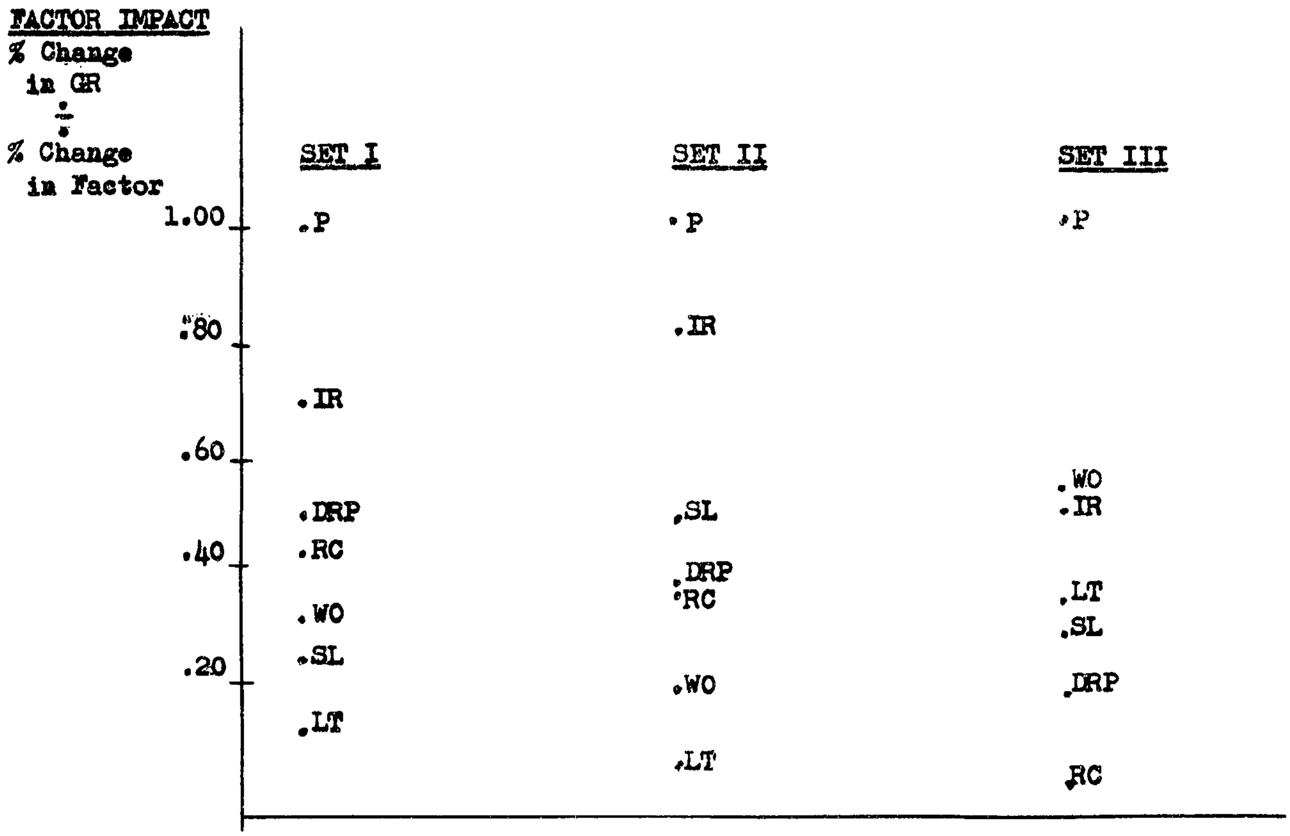
b. Those which are not combined through multiplication influence one another's Impact inversely.

As an example of the above, and by reference to Equation 2, the larger the Issue Rate the greater the Impact of the Stock Level, the smaller the Impact of Wearout Rate and Lead Time.

By looking back at Figure III, we can see that the Stock Level had a fairly strong Impact because it was associated with the Issue Rate. The Issue Rate in turn had a strong Impact because it was so much larger than the Wearout Rate. If the item had had a much higher Wearout Rate, its Issue Rate and Stock Level would have had sharply reduced Impacts. Any interactions of this kind in which one has a special interest can be fairly easily interpreted from Figure III if one keeps this basic principle in mind: a percentage change in a factor has great importance or not, depending on the proportion of the original requirement to which that factor contributed.

The Impact values discussed up to now all relate to the particular "standard" or starting values that were assigned by Figure I. By varying these, as is done in Figure V, we can see that the Impacts are substantially changed. For example, LT is relatively unimportant with Factor Sets I and II (because it is associated with Wearout Rate, which was only one-tenth and one-twentieth of Issue Rate in those Sets); however LT becomes considerably more important in Set III (because there its associated Wearout Rate is one-fifth of the Issue Rate). Note also how RC drops sharply in importance in Set III, primarily because of the down-grading effect of the low Depot Repair Percentage. Figure V suggests that broad generalizations about the importance of specific factors cannot be made abstractly, but must be based upon empirical examination of the relative frequencies of certain factor relationships in real life, particularly the IR/WO ratio.

FIGURE V



ALTERNATIVE FACTOR VALUES

	SET I	SET II	SET III
P	Any value	Any value	Any value
LT	9 mos	6 mos	12 mos
RC	3 mos	2 mos	5 mos
SL	1½ mos	2 mos	2 mos
IR	.0020/FH	.0020/FH	.0010/FH
WO	.0002/FH	.0001/FH	.0002/FH
DRP	100%	75%	30%

If the care and the cost which are justifiable in factor development are properly relatable to the Impact of the respective factors, and since the Impact of a particular factor can vary considerably, it would appear that many data processing decisions need to be made on a case-by-case approach. For example, if members of a Hi-Valu Review Board are having some difficulty in determining the correct value of some factor, for a particular line item, they should compromise expeditiously if the Impact is low, but go to considerable lengths to get the best value of the factor if its Impact is high.

Effects After Procurement

Up to this point, we have discussed factor Impacts from a pre-procurement perspective. For consideration of factor relationships after procurement actions, we need merely take Figure III and replace Gross Requirements (GR) by Stocks on Hand, then view the latter as a fixed quantity. It then becomes possible to study how an increase or decrease in one factor leads to forced decreases or increases respectively in some others. A few examples follow.

Let us assume that wearouts, after the buy, run at .0004 per flying hour in lieu of the anticipated .0002. After six months, 12 units more than expected will have worn out (10,000 x 6 x .0004 vs. 10,000 x 6 x .0002); since the depot stock objective is one-third of the total stock level (namely, one-third of the 30 units in Figure III), this variance in wearout could eliminate our depot stock level.

Take a different possibility, namely, repair cycle running at 4½ months instead of the planned 3 months, due to slow contrast repair and/or misrouted shipments. Instead of tying up the 60 units shown in Figure III, this slower repair will tie up 90 units and cause all serviceable stock levels to disappear.

As a third example, consider an issue rate which has increased a mere 15% from the specified .0020 per FH to .0023. A 3-month repair cycle will then hold 69 units instead of the 60 shown in Figure III, so the 30 units originally planned for base and depot serviceable stock levels will have to yield 9 units to the repair cycle. Then if the bases raise their stock level from 20 to 23 they will be slightly short (21 instead of 23) and the depot will be out of stock.

Now consider a final example, where the worldwide issue rate remains at an average of .0020 per FH, but half the bases temporarily experience a rise in the rate to .0035 and the other half experience only .0005 issues per FH. On the assumption that bases are probably quicker in reacting to increases in demand than they are in reacting to decreases, half the bases will raise their stock levels from a total of 10 to 18, the other half will not lower their stock levels, and depot stocks will almost disappear. This example is considered to be particularly enlightening where Hi-Valu items are concerned, since AMC depends heavily on user command requests in setting the Hi-Valu base stock levels - the audit or control of such requests is almost impossible because pre-issue methodology leaves AMC without adequate knowledge of logistic experiences at base level.

The last example also illustrates fairly realistically how random variations in demand could cause AMC to react by deciding that more procurement is needed - when in truth we may be experiencing maladjustments of stock distribution which should be corrected by stronger control of base stock levels and by short term expediting (e.g., project HOT SHOT).

Breadening the Problem

The problems discussed above could be broadened further through consideration of the following:

a. War readiness materiel requirements and requirements for special projects lessen the Impact of all the factors discussed above.

b. The inherent variability or "random" behavior of any factor lessens our ability to measure it accurately - even if we had a constant environment with failure rates, programs, etc., all holding firm. In the discussion above we tacitly assumed that all the factors were accurately measured. When we consider how sensitive the system is to factor Impacts "after the buy," it is easy to see that difficulty in measuring the factors can lead to poor decisions about the corrective measures needed.

c. Changes in the environment (program changes, ECPs, new policies, revised objectives, etc.) severely reduce our measurement capabilities.

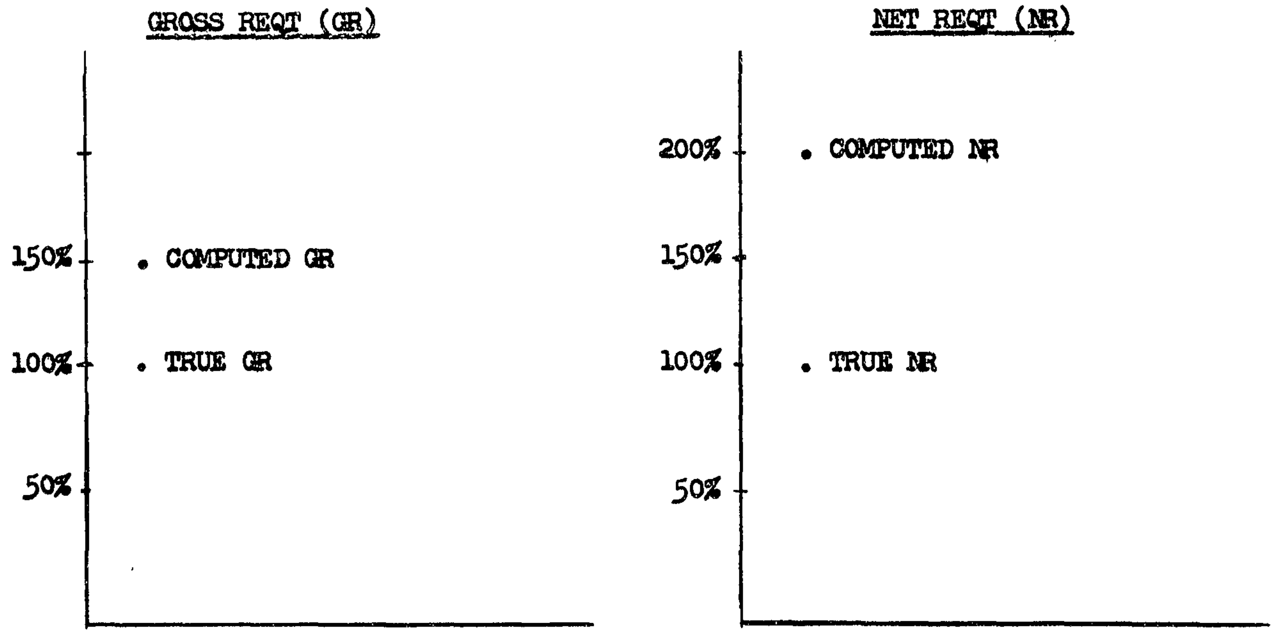
d. Errors in the data system compound the problem.

e. The factor Impact on Gross Requirements is small compared to the Impact on Net Requirements.

Paragraph a above is rather self evident. Paragraphs b through e are briefly illustrated in Figure VI below, wherein the "errors" are the result of a miscalculation of some factor. It is seen that these errors have much greater Impact on the net requirement than on the gross requirement, with a relationship as follows:

$$I_N = (I_G)\left(\frac{\text{True Gross Requirement}}{\text{True Net Requirement}}\right)$$

FIGURE VI



TRUE GROSS - 300 UNITS

COMPUTED GROSS - 450 UNITS

ERROR + 50%

TRUE NET - 150 UNITS

COMPUTED NET - 300 UNITS

ERROR + 100%

The errors shown in Figure VI can readily be compounded further if there is erroneous SB&CR information on assets available in the system. Thus, if we thought we had only 100 assets when we really had 150, we would have a computed Net Requirement of 350, an error of + 133%.

"Too Much Accuracy"

Since this report is related to a project on data simplification, it is well to point out that too little accuracy in data is not our only data problem; there is also a possibility of striving for "too much accuracy." In our data reporting and data processing systems there are undoubtedly situations where "accuracy" to many decimal places is carefully (and expensively) preserved for certain data elements beyond the level that is reasonable when we consider the overall accuracy of the system. It might be useful to keep in mind that requirements calculations are beset by so many uncertainties that accuracy within 1% is an extremely ambitious goal. Consequently, where increases in data accuracy require increases in expense, only rarely would accuracy beyond the first two or three significant places be justified. For example, this means that a logistic factor or rate measured as .023500 is to be preferred to that element measured as .023478 if it is more costly to process the latter way.

This does not mean that free information should be deliberately thrown away - for example, it does not mean that data obtained by an inventory process should be automatically rounded to two significant figures. It does mean, however, that expensive procedures should be avoided if they do not improve the accuracy of the first two significant figures of our final results.

Impacts on Flexibility

Lest this paper be interpreted as a complete method of evaluating the relative importance of the factors discussed, it is well to note that our factors influence other things besides gross requirements. They have important effects insofar as flexibility and responsiveness are concerned. Thus, if procurement lead times are low for an item on which shortages are developing, we have more opportunity to find other answers to our problems rather than a new buy: perhaps an engineering improvement; perhaps a longer wait to see whether recent increases in demand were basic or mere random fluctuations; perhaps an opportunity to work with using commands on faster shipment of reparables to depots, and so forth.

As another illustration, let us take an adverse effect, for example, one in which stock level is cut so low that we have high probabilities of stockouts. The low stock level may have small impact on gross requirements but very large impact indeed on the overall efficiency and readiness of the combat mission. Full evaluation of factor importance obviously requires a study considerably more extensive than this one.

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